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|---|---|---|---|
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| 2. | Patent application number *(The Patent Office will fill in this part)* | **9902758.3** | - 8 FEB 1999 |
| 3. | Full name, address and postcode of the or of each applicant (*underline all surnames*) | H B Fuller Coatings Ltd<br>95 Aston Church Road<br>Nechells<br>Birmingham B7 5RQ | and Security Composites Limited<br>The Glade<br>Redhill<br>Hookagate<br>Shrewsbury<br>Shropshire SY5 8BP |
| | Patents ADP number (*if you know it*) | 7352388001 | 7598303001 |
| | If the applicant is a corporate body, give the country/state of its incorporation | GB | GB |
| 4. | Title of the invention | HEAT TRANSFER ELEMENT | |
| 5. | Name of your agent (*if you have one*) | **W.P.THOMPSON & CO.** | |
| | "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* | Celcon House<br>289-293 High Holborn<br>London<br>WC1V 7HU | |
| | Patents ADP number *(if you know it)* | 158064 158007 | |
| 6. | If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number | Country / Priority application number *(if you know it)* | Date of filing *(Day/month/year)* |
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| 8. | Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'yes' if:*<br>*a) any applicant named in part 3is not an inventor, or*<br>*b) there is an inventor who is not named as an applicant, or*<br>*c) any named applicant is a corporate body.*<br>*See note (d))* | Yes | |

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

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11. I/We request the grant of a patent on the basis of this application

Signature Date 08/02/99

W.P.THOMPSON & CO.

12. Name and daytime telephone number of person to contact in the United Kingdom

Dr C.T. Eyles
0171 242 3524

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# HEAT TRANSFER ELEMENT

## Background of the Invention

1. Field of the Invention

The present invention relates to a heat transfer element, more particularly to a heat transfer element for use in a power generating station or a chemical processing plant.

2. Background

There are currently over six hundred power generating stations in the European Union. An important feature of these stations is the provision of heat exchangers consisting of a number of radiant panels which serve to transfer heat within the station. There may be around 30,000 square metres of radiant panels in a single heat exchanger. A power generating station may use up to twelve or more heat exchangers.

The radiant panels should not only serve their primary heat transfer function, they should also be robust to withstand the conditions in which they operate. Thus, not only are physical conditions harsh, with hot air and steam at up to about 150°C flowing at high speed past the panels, but also corrosive chemicals, such as sulphurous and nitrous acids, are present in the air stream. Furthermore, the panels may become clogged with soot or debris, which may also impair their function. The panels are also subjected to rapid thermal cycling.

Conventionally, heat transfer elements used to make the radiant panels have been manufactured from a metal with a vitreous enamel coating. The metal base material, conveniently of mild steel, provides the necessary structural strength to the element and also the required thermal conductivity. A coating of vitreous enamel protects the metal base from the corrosive effects of the surrounding environment. Recently, attempts have been made to provide heat transfer elements by spraying a metal base with a fluoropolymer. However, the resulting composite element is not economical to manufacture. There is a need to improve

upon the performance of heat transfer elements in power generating stations. Thus, it would be desirable to provide a heat transfer element with improved heat transfer properties, with improved anti-fouling properties, with improve resistance to physical and chemical corrosion, and with improved mechanical properties. All of these desiderata are objects of the present invention. A further object of the present invention is to provide a heat transfer element with the improved properties referred to above but which is economical to manufacture.

Summary of the Invention

Accordingly, the present invention provides a heat transfer element comprising:

a polymer sheet having a fibrous material interspersed therein and comprising a fluoropolymer at least on an outer surface of the sheet, the interspersion of the fibrous material within the sheet providing rigidity to the element; and

a thermally conductive material distributed within the heat transfer element.

The heat transfer element of the invention has a number of significant advantages over conventional heat transfer elements, in particular the conventional elements used to form the radiant panels of power generating stations. The provision of a fluoropolymer sheet significantly improves the anti-fouling properties of the heat transfer elements of the invention. Fluoropolymers have low surface energy and good lubricity and are therefore able to resist fouling by soot and debris to a greater extent than has been the case with conventional ceramic materials. Furthermore, fluoropolymers tend to be extremely resistant to chemical attack and are well adapted to withstand the corrosive action of the sulphurous and nitrous acids present in the air stream flowing past the elements when in use. This resistance to chemical attack prevents surface solvation, which could otherwise worsen the flow characteristics of the surface.

Detailed Description of the Invention

In one embodiment of the invention, the fibrous material is itself a thermally conductive material, for example a metal such as stainless steel.

One advantage of using a thermally conductive material as the fibrous material is that it may not then be necessary to provide any further thermally conductive material in the element. In this case, the fibrous material will itself serve as the sole thermally conductive material in the element. However, it may in some cases be preferred to distribute a thermally conductive material within the element by means other than the fibrous material. Thus, in one preferred embodiment of the invention, the thermally conductive material comprises a particulate or filamented material, for example, a particulate or filamented metal such as iron or steel. This particulate or filamented material may be mixed with the fluoropolymer prior to compression molding or lamination of the fluoropolymer onto the fibrous material. The resulting heat transfer element according to the invention will comprise a fibrous material, which may if desired be of metal or some other thermally conductive material but which may also be a thermal insulator, such as fibre glass, and a fluoropolymer sheet having the thermally conductive particulate or filamented material distributed within the fluoropolymer sheet.

The polymer sheet may consist entirely of a fluoropolymer or admixtures of a fluoropolymer with compatible thermoplastic polymers, antioxidants and other additives. In this case the fibrous material is interspersed within the fluoropolymer. However, in an alternative embodiment of the invention, the polymer sheet may comprise an underlayer of a plastics material, in which the fibrous material is interspersed, and an overlayer of fluoropolymer. The plastics material is preferably an acrylic polymer or alloy. This arrangement may be desirable for economic reasons. When the plastics material, such as a relatively inexpensive acrylic polymer, is laminated or

compression molded onto the fibrous material, the thermoplastic acrylic polymer flows into and around the fibres and provides a relatively cheap filler onto which the fluoropolymer may be coated. Of course, the lamination or compression molding of the fibrous material with the inexpensive acrylic filler and the fluoropolymer may be done simultaneously by applying heat and pressure to a sandwich having an outer film of fluoropolymer, an intermediate layer of acrylic polymer and an inner layer of fibrous material. In this case, the fibrous material may become interspersed in both the acylic polymer and the fluoropolymer.

The use of compression molding or lamination, for example continuous belt lamination, to form the heat transfer element is preferred. However, it may sometimes be approriate, for example when an inexpensive acrylic polymer is used, to powder coat the fluoropolymer onto a base portion formed after cooling of the acrylic base sheet with interspersed fibrous material. However, the use of compression molding or lamination allows the manufacturer to minimise the thickness of the coating, thus improving the thermal transfer properties of the element and allowing cost-effective manufacture of the element by minimising the quantity of the expensive fluoropolymer used therein.

The heat transfer element of the invention may also be formed as a tube by extrusion of a fluoropolymer melt and interspersed fibrous material.

The fluoropolymer used in the present invention is preferably a fluorohydrocarbon polymer, such as polyvinylidene fluoride (PVDF) or a copolymer with at least 80% by weight of vinylidene fluoride and up to 20% by weight of at least one other fluorine based monomer. Suitable fluorine based monomers which may be used with vinylidene fluoride are tetrafluoroethylene, hexafluoropropylene and vinylfluoride, having the characteristics listed in U.S. Patent Nos 4,770,939 and 5,030,394. The fluoropolymer is most preferably PVDF and is commercially available from Atochem North America, Inc. under the trade designation

KYNAR 500 PC, KYNAR 710, KYNAR 711 or KYNAR 2800.

The fluoropolymer may be mixed with another thermoplastic polymer. The preferred thermoplastic polymers are acrylic polymers with units derived from acrylates or methacrylates, such as copolymers derived from an alkyl acrylate or alkyl methacrylate, preferably, methyl methacrylate or from at least one other olefinically unsaturated monomer. Acrylic acid and methacrylic acid are also suitable as the other olefinically unsaturated monomer. Advantageously, the copolymers comprise at least 75% by weight of units derivable from an alkyl methacrylate and up to 25% by weight of units derivable from one or more other olefinically unsaturated monomers. The thermoplastic polymer is preferably poly(methyl acrylate) or poly (methyl methacrylate) or an alkyl methacrylate/alkyl acrylate copolymer. These thermoplastic polymers have the characteristics listed in U.S. Pat. Nos. 4,770,939 and 5,030,394 and are commercially available from Rohm & Haas Company under the trade description Acryloid/Paraloid B-44®. These materials are described in U.S. Patent No. 5, 229, 460. Another preferred acrylic polymer is available from Atohaas under the trade designation OROGLAS HFI-10.

The use of an acrylic polymer in admixture with the fluoropolymer can improve the wetting properties of the material and thus help to ensure even coating of the fibrous material in the heat exchange element of the invention.

The weight ratio of the fluoropolymer to the thermoplastic acrylic polymer, if used, is preferably in the range of from about 90:10 to 40:60, preferably from about 75:25 to 65:35, for example about 70:30.

A low melting point fluorine-based terpolymer may also be added to the fluoropolymer/thermoplastic acrylic polymer mixture. A terpolymer is a polymer made from three monomers. Such a low melting point terpolymer would have, for example, a melting point of not higher than 150°C. A suitable terpolymer is vinylidene fluoride-tetrafluoroethylene-hexafluoropropylene, having a melting

temperature of about 87° to 93°C and a melt viscosity of about 11,000 to 13,000 Poise at 125°C. The preferred terpolymer is commercially available from Atochem, North America, Inc. under the trade designation KYNAR ADS®. The weight ratio of the fluoropolymer to the terpolymer, if used, is in the range of from about 50:50 to 99:1.

The mixture may also contain other additives, such as corrosion inhibiting pigments, dry flow promoting agents, antioxidants, adhesion promoters and ultra-violet-absorbing materials, although not required. One preferred additive is an antioxidant, such as 2,2-bis[3-[3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl]-1-oxopropoxy]methyl]-1,3-propanediyl 3,5-bis(1,1-dimethylethyl)-4-hydroxybenzene-propanoate, available from Ciba-Geigy under the trade designation Irganox 1010.

In order that the invention may be properly understood and fully carried into effect, a number of preferred embodiments thereof will now be more particularly described in the following Examples:

**Example 1**

A fluoropolymer composition comprising the following ingredients was prepared:

| Raw Materials | % by weight |
|---|---|
| Kynar™ 710 | 69.3% |
| Paraloid™ B-44 Beads | 29.7% |
| Irganox™ 1010 | 1.0% |

The materials were mixed in a high speed MIXACO™ mixer and fed into a twin screw extruder and extruded at about 200°C. The extrudate was quenched in a water bath and then pelletised.

The pelleted composition was extruded through a single screw extruder with a single slot die to form a continuous film with a thickness of around 120μm.

The resulting film was used to coat a fibrous pad of mild steel by placing a sheet of film on each side of the

pad and subjecting the covered pad to a temperature of 200°C and a pressure of 0.625 tonnes per square inch (95 bar) in a heating press.

The resulting heat transfer element has excellent heat transfer, anti-fouling, structural and flow characteristics.

**Example 2**

A film of fluoropolymer coating composition was prepared as described above in Example 1 and was used to coat a fibrous mild steel pad by covering both sides of the pad with film and passing the covered pad through a twin belt laminator. Acetate release sheets were placed over the fluoropolymer film to prevent adherence of the fluoropolymer to the belts of the laminator.

The resulting heat transfer element has excellent heat transfer, anti-fouling, structural and flow characteristics.

**Example 3**

A fluoropolymer coating composition as specified in Example 1 was prepared and mixed with stainless steel filings in a ratio of three parts by weight of the coating compostion to one part by weight of stainless steel filings. The resulting composite material was laminated onto a fibre glass pad using the method described in Example 2 to form a heat transfer element with excellent heat transfer, anti-fouling, structural and flow characteristics.

**Example 4**

Examples 1 to 3 were repeated using a fluoropolymer composition of the following ingredients:

| **Raw Materials** | **% by weight** |
|---|---|
| Kynar™ 2800 | 60.00% |
| Oroglas™ HFI-10 | 40.00% |

In each case, a heat transfer element with excellent heat transfer, anti-fouling, structural and flow characteristics was produced.

CLAIMS:

1. A heat transfer element comprising:

a polymer sheet having a fibrous material interspersed therein and comprising a fluoropolymer at least on an outer surface of the sheet, the interspersion of the fibrous material within the sheet providing rigidity to the element; and

a thermally conductive material distributed within the heat transfer element.

2. A heat transfer element according to claim 1, wherein the fibrous material is of a thermally conductive material such that the distribution of thermally conductive material within the heat transfer element is provided, in whole or in part, by the fibrous material.

3. A heat transfer element according to claim 2, wherein the fibrous material is of stainless steel.

4. A heat transfer element according to claim 2, wherein the fibrous material is fibre glass.

5. A heat transfer element according to any one of claims 1 to 4, wherein an intermediate layer of a plastics material is provided underneath the outer fluropolymer surface of the element.

6. A heat transfer element according to claim 5, wherein the plastics material is an acrylic polymer.

7. A heat transfer element according to any one of claims 1 to 6, wherein the thermally conductive material comprises a particulate or filamented material.

8. A heat transfer element according to claim 7, wherein the particulate or filamented material is a metal.

9. A heat transfer element according to any one of claims 1 to 8, wherein the fluoropolymer comprises PVDF.

10. A heat transfer element according to any one of claims 1 to 9, wherein the fluoropolymer is mixed with another thermoplastic polymer.

11. A heat transfer element according to claim 10, wherein the other thermoplastic polymer is an acrylic polymer.

12. A tubular heat transfer element according to any one of claims 1 to 11, formed by extruding a mixture of fluoropolymer, fibrous material and, where necessary, particulate or filamented thermally conductive material.

13. A process for the production of a heat transfer element according to any one of claims 1 to 11 comprising providing a fibrous base portion, optionally of a thermally conductive material, and forming by compression molding or lamination over the surface of the base portion a coating of a fluoropolymer, including if necessary the step of distributing a thermally conductive material within the element.

**ABSTRACT**

The invention relates to a heat transfer element for use in the manufacture of radiant panels for power generating stations. The heat transfer element comprises a polymer sheet having a fibrous material distributed therein providing structural strength and a fluoropolymer at least on an outer surface of the element which protects the element from physical and chemical corrosion whilst providing anti-fouling properties and good flow characteristics to the element. A thermally conductive material is distributed within the element to provide the necessary heat transfer characteristics.